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Original Research

Evaluation of the Olecranon Bursa: An Anatomical Structure in the Normal Horse

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ABSTRACT

This study aimed to determine whether a true synovial structure exists over the olecranon tuberosity, which could be attributed to a noninflamed olecranon bursa. Contrast radiography, gross anatomical dissection, and histopathology were used to evaluate the olecranon bursa in horses with no previous elbow pathology. The radiographic study revealed that the contrast was positioned subcutaneously, superficial to the long head of the triceps and its insertion on the olecranon tuberosity and did not extend cranial to the triceps tendon. The contrast region was consistent in shape, size, and location. Gross anatomical dissection of the area revealed a potential bursal space overlying the tendons of the lateral and medial heads of the triceps brachii and the tensor fascia antebrachii in the normal horse. Histopathology confirmed a bursal lining, which was of mesenchymal origin and suggestive of a single-cell membrane, lined by fibroblast-like synoviocytes.

1. Introduction

There is a paucity of literature available assessing the anatomical boundaries of the olecranon bursa in the horse and whether the structure is congenital. Although infrequently injured, when trauma occurs, management of olecranon bursitis can be complex [1]. Knowledge of the anatomical boundaries and histology of the bursa in horses with no elbow lesions may assist the clinician in making appropriate treatment decisions.

Bursae are closed, fluid-filled structures that are interposed between structures subject to friction or at locations of increased pressure, such as bony prominences and tendons [2]. Bursae are usually described based on their anatomical location, whether they are deep (sub or intertendinous, subligamentous) or superficial (subcutaneous) and whether they are congenital or acquired [3]. The olecranon tuberosity is the site of insertion of the tendons of the elbow extensor muscles [4]. The three heads of the triceps brachii muscle (lateral, long, and medial) insert onto the caudolateral aspect of the olecranon [5]. The anconeus muscle originates from the distal humerus, lies deep to the triceps, and inserts laterally onto the olecranon [6]. The tensor fascia antebrachii overlies the triceps caudolaterally, originates from the proximal lateral scapula, and inserts onto the lateral olecranon [6] (Fig. 1).

A common cause of inflammatory olecranon bursitis is repetitive trauma of the olecranon region from the horse's hoof or from ground contact when laying down. Other causes include nonrepetitive trauma such as a wound or a penetrating injury, which can lead to septic bursitis. Infection through hematogenous spread has also been reported to contribute to olecranon bursitis [1].

Treatment of olecranon bursitis comprises both medical and surgical techniques. Medical management includes draining the fluid from the bursa and injecting corticosteroids, used mainly in acute bursitis, with variable success [1]. Surgical management via either drain placement or complete resection of the bursa appears to have more successful outcomes, compared with conservative management techniques [7,8].

Previous imaging studies in horses have failed to identify a noninflamed olecranon bursa [4]. However, a human cadaver study

Animal welfare/ethical statement: Owner consent was gained before euthanasia for the inclusion of each horse in the study. No further consent for ethical considerations was required for this study.

Conflict of interest statement: The authors declare no conflicts of interest.

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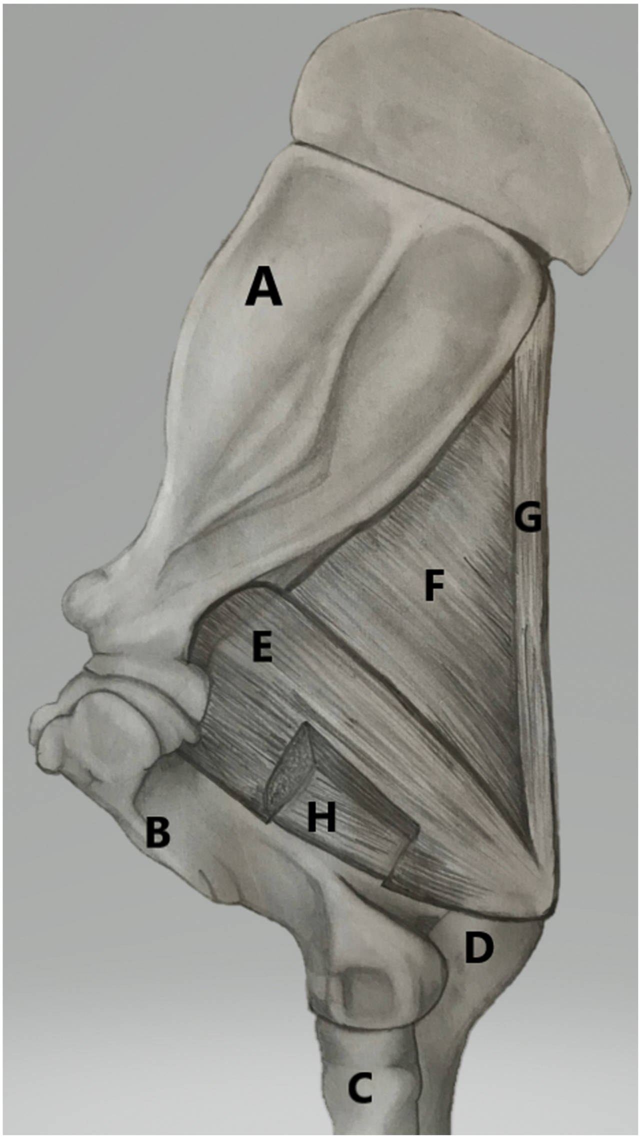

Fig. 1. Drawing of the extensor muscles of the elbow. (A) Scapula bone, (B) humerus bone, (C) radius bone, (D) olecranon of the ulna bone, (E) lateral head of the triceps muscle, (F) long head of the triceps muscle, (G) tensor fascia antebrachii muscle, and (H) anconeus muscle laying deep to the lateral head of the triceps.

showed that the olecranon bursa is present as a normal anatomical structure in the absence of injury in man [9], but the literature in humans states that a normal bursa, which is not distended with fluid, is difficult to identify [10–12].

This study aims to determine a location of the olecranon bursa and surrounding anatomy, the extent of the olecranon bursa and whether the bursa has a synovial lining in the normal horse. It was hypothesized that the olecranon bursa in the horse is a subcutaneous structure that is present without trauma to the olecranon tuberosity and that there is a synovial lining present.

2. Materials and Methods

The inclusion criteria for the study included horses older than 1 year, that weighed more than 100 kg, and had no known history of elbow lesions. Horses were humanely euthanized for other reasons. Owner permission was granted before their horse's inclusion in the study. Once the number of limbs for each part of the study was reached the next part of the study commenced, there was no randomization for allocation of limbs.

2.1. Radiographic Contrast Study

Within 30 minutes of humane euthanasia, a 20-gauge 38-mm needle (Agani Needle; Terumo UK Ltd., Otium House, 2 Freemantle Road, Bagshot, Surrey, GU19 5LL, UK.) was inserted directly over the most protuberant and caudal point of the olecranon tuberosity perpendicular to the skin. The cadaver was positioned in lateral recumbency with the limb to be imaged uppermost. The limb was held in slight flexion by an assistant, the needle was advanced until there was contact with the olecranon tuberosity. The needle was withdrawn approximately 2 mm until 5 mL of iohexol (GE Healthcare AS, Nycoveien 1-2 NO-0401, Oslo, Norway) 300 mg/mL could be injected without resistance. Lateromedial (LM) and craniocaudal (CrCa) radiographic views of the elbow region were obtained in the same position as injection.

All images were imported into a measuring program, 'IC measure' (The Imaging Source Europe GmbH, Überseetor 18, 28217 Bremen, Germany). The first author obtained all measurements. The LM view allowed proximal to distal measurements and cranial to caudal measurements of the contrast area to be obtained. The CrCa view allowed lateral to medial measurements of the contrast area to be obtained. The measured distances on the radiographs were calibrated to ensure accurate measurements were obtained independent of film-focal distance. The contrast area was measured three times and the mean obtained (Figs. 2 and 3).

2.2. Gross Anatomy of the Bursa in Cadaver Specimens

Colored silicone rubber mixture consisting of 10 parts silicone rubber (Silicone Mold Rubber; Tiranti, 3 Pipers Court, Berkshire Drive, RG19 4ER, UK), one-part catalyst (T6 Catalyst; Tiranti), five parts silicone thinner (Silicone Fluid; Tiranti), and two parts blue coloring (Opaque Blue Polyester Pigment; Tiranti) was injected via the same technique as the contrast study detailed previously. Injection was performed using a 16-gauge 38-mm inch needle (Agani Needle; Terumo). The silicone rubber mixture was allowed 24 hours to cure before dissection. An elliptical skin incision was made with a No.10 scalpel blade. The incision extended 4 cm proximal and 4 cm distal to the olecranon tuberosity. Blunt dissection was performed using Metzenbaum scissors to release the fascial tissues between the skin and bursa. The soft tissue surrounding the silicone was dissected using both blunt and sharp dissection techniques, which consisted of releasing the mass from its underlying connections. This included the tendon of the tensor fasciae antebrachii and tendons of the lateral and the medial heads of triceps brachii [6].

A single olecranon tuberosity was injected with the same latex mixture, as detailed previously, and frozen for 1 week. A band saw was used to divide the elbow along the sagittal plane.

2.3. Histopathology

A 5 mL of 10% formalin (Formalin; Vet-Way LTD, 1 Harrier Court, Airfield Business Park, Elvington, York, YO41 4EA, UK) was injected over the olecranon tuberosity using the same technique as the contrast study detailed previously. This technique was performed to fill the area with a medium that would not interfere with histopathology but made visualization of the capsule easier during dissection. The dissection technique was the same as for the gross anatomy study detailed previously. Tissue samples for light microscopy were fixed overnight in 10% neutral-buffered formalin

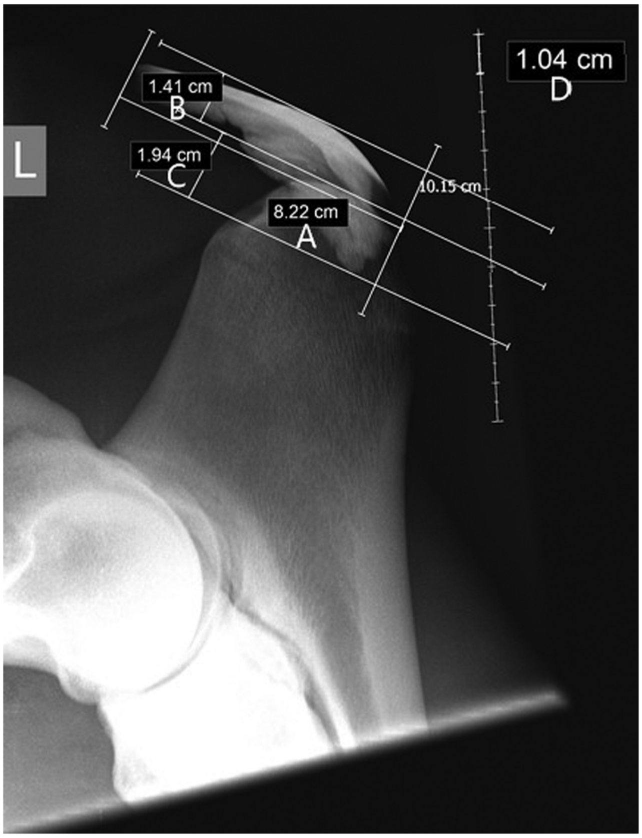

Fig. 2. Lateromedial radiograph of the elbow region following iohexol injection over the olecranon tuberosity. Lines drawn for measurements. (A) Proximal–distal measurement, (B) distance from the caudal aspect of the contrast area to the olecranon tuberosity, (C) cranial to caudal measurement of the contrast, and (D) calibration measurement.

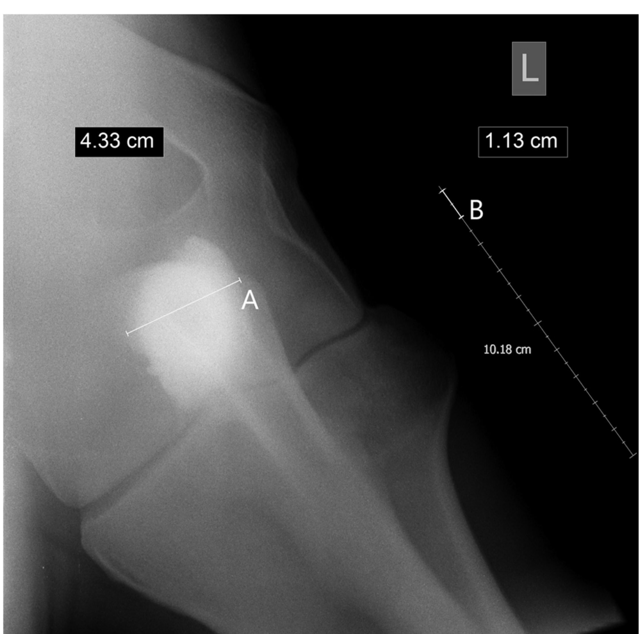

Fig. 3. Craniocaudal radiograph of the elbow region showing iohexol at the point of the olecranon. (A) Lateromedial measurement and (B) calibration ruler measurement.

submitted for routine histopathology to the University of Liverpool Veterinary Diagnostic Service, were they were trimmed, paraffin embedded, and stained with hematoxylin (Haematoxylin; TCS Biosciences Ltd, Buckingham, UK; HD1475) and eosin (Eosin; TCS Biosciences Ltd, Buckingham, UK; HS250-1L). Selected 3-μm histologic sections were stained using the following special stains: Alcian blue at pH 2.5 (Alcian Blue 8GX; HD1040, HD Supplies, Aylesbury, UK) in 3% acetic acid (Glacial Acetic Acid, Fisher, A/0360/PB17), or 50% w/v aqueous periodic acid (Aqueous Periodic Acid; TCS Biosciences Ltd, HC6455-50), and Schiff (Schiff; Solmedia, HST206-D). Further 3-μm histologic sections were selected and stained using the EnVision FLEX Target Retrieval Solution (TRS) High pH, Tris/EDTA buffer pH 9 (DM828) with the following primary antibodies: primary antibody diluted 1:200 Monoclonal Mouse Anti-Human Cytokeratin (Dako Corp., Carpinteria, CA; M3515) or primary antibody diluted 1:500 Monoclonal Mouse anti-Vimentin, clone V9 (Dako Corp.; M0725). Positive control sections were included for each antibody, whereas negative controls lacked primary antibodies.

3. Results

There was a total of 22 horses in this study. Ages ranged from 1 to 28 years with a mean age of 11 years. There were seven mares, 13 geldings, and two stallions. There were 13 horses in the radiographic contrast study (26 bursae imaged), five horses in the gross anatomical study (eight bursae in situ assessed and one bursae band sawn), and four horses in the histopathology study (eight bursae assessed).

3.1. Radiographic Contrast Study

All images were given an I.D. number, which consisted of horse number and left limb or right limb. All horses were numbered 1–13. The right limb was denoted .1 and the left limb was denoted .2 (e.g., the image of the left leg of horse number 1 was I.D. number 1.2). There was a total of 52 radiographic images (26 LM and 26 CrCa).

The quality-control criteria of radiographic images for inclusion in the study were a well-defined contrast area with minimal obliquity. Images were assessed by the author to ensure the contrast column was clearly visible before accepting for measurement. No images were rejected in this study.

3.1.1. LM Images

In all radiographs, there was consistency in the shape and position of the contrast area in relation to the olecranon tuberosity. The density of contrast in all images was greatest in the mid portion and tapered proximally and distally.

The length of the contrast area followed a normal distribution with a mean of 6.18 cm, a standard deviation of 1.17 cm, and demonstrated that 95% of the population have a proximal-distal contrast column between 5.8 and 6.7 cm (Table 1).

3.1.2. CrCa Images

The contrast area was easily distinguishable from the olecranon tuberosity. All images had a consistent circular-shaped radiodensity. The width of the contrast area followed a normal distribution with a mean of 4.36 cm, a standard deviation of 0.77 cm, and that 95% of the population have a lateral–medial width of contrast size between 4.06 and 4.65 cm (Table 2).

3.2. Gross Anatomy of the Bursa in Cadaver Specimens

All limbs were in partial flexion. Undermining of the tissues medially and laterally was required. Once the overlying fascia was

Table 1
LM radiographic contrast area measurements.

Measurement	Shortest (cm)	Longest (cm)	Range (cm)	Mean (cm)
Length of contrast area	4.34	9.98	5.64	6.18
Distance from the contrast area to the olecranon tuberosity	0.62	2.12	1.5	1.12
Distance from the most caudal aspect of contrast area to the most cranial aspect	1.98	4.99	3.01	3.18

Abbreviation: LM, lateromedial.

released, the proximal to distal and lateral to medial extent could be visualized and dissection planes assessed. In all horses, the silicone was firmly attached to the underlying tendons and overlaid the tendons of the lateral and medial head of the triceps brachii and the tensor fasciae antebrachii [13] (Figs. 4A and 5B).

Gross anatomy in the cadaver limb that was sectioned in the sagittal plane included the long head of the triceps brachii. The tendon of this muscle belly could be seen running over the olecranon tuberosity with the silicone mixture overlying it in the subcutaneous space (Fig. 5). This was consistent with a potential subcutaneous space with no extension of mixture through to deeper structures either proximally or distally. This pattern of distribution was consistent with the findings of the contrast study.

3.3. *Histopathology*

The olecranon bursae of all horses exhibited similar histomorphological multilayered architectures and cellular characteristics. The bursal lining composed of single-cell thick membranes of spindloid cells with indistinct cell borders, scant to moderate fibrillary pale eosinophilic cytoplasm and plump spindloid nuclei with homogenous basophilic chromatin (Fig. 6). In all bursae, these cells demonstrated strong immunohistochemical cytoplasmic positivity for mesenchymal vimentin intermediate filaments whilst epithelial pancytokeratin intermediate filaments were not detected (Fig. 7). These delicate membranes were supported by a loose underlying, moderately cellular, stroma comprised predominantly of Alcian blue positive (at pH 2.5)/periodic acid−Schiff (PAS) negative mucopolysaccharides (acid-simple mesenchymal mucin) with a moderate population of interspersing plump spindloid cells (Fig. 8; 10 × 40 μm), with scant to moderate fibrillary to finely granular, lightly eosinophilic, strongly Vimentin-positive/pancytokeratin-negative cytoplasm and plump to spindloid nuclei with finely stippled basophilic chromatin. Moderate numbers of mature variable caliber blood vessels sparsely infiltrated the stroma, supported by small quantities of perivascular collagenous stroma. The deepest layers of these structures were contiguous with underlying skeletal myofibers and collagenous stroma. The bursal roots (attachment to the triceps brachii tendon) were present in four bursae; these exhibited identical bursal lining and stromal composition compared with the bursal body; however, were more densely packed and had greater associated vasculatures.

The main components of the olecranon bursae histologically support the hypothesis that the structure observed grossly is not associated with an inflammatory component because of a complete absence of leukocytes throughout both submitted samples. The lining of the bursae was identified to be of mesenchymal origin (Vimentin-positive) and was most suggestive of a single-cell membrane lined by fibroblast-like synoviocytes (type B synoviocytes). The main matrix component of the underlying stroma was identified as an acid-simple mesenchymal mucin, as indicated by Alcian blue positive (at pH 2.5) and PAS negative staining; in addition, the main cellular stroma population was similarly identified as mesenchymal, with fibroblastic/fibrocytic morphology.

4. Discussion

This study demonstrates that there is a noninflamed bursa at the olecranon tuberosity between the skin and the tendon of insertion of the heads of the triceps brachii, in a normal horse older than 1 year. Neither the contrast nor the silicone rubber mixture coursed deep to the triceps tendon, concluding the subcutaneous nature of the bursa.

There was consistency of the contrast area both during injection and when viewed radiographically. On all LM views, the contrast was curved over the olecranon tuberosity, showing consistency in shape and position. The contrast area ranged in size between horses, likely due to the variation in size of horse.

In human cadaveric studies, it has been determined that the olecranon bursa develops between the ages of 7 and 10 years. It is an acquired subcutaneous structure in humans but develops regardless of whether there is injury to the area and increases in size over time. The olecranon bursa of adults is described as a consistent structure that is always visualized and likely develops because of recurrent pressure and friction to the point of the olecranon [9]. Ultrasound evaluation of the human olecranon bursa reveals a thin hypoechoic region because of a small amount of fluid that is easily dispersed from the area when pressure is applied, but is difficult to identify when not distended [10]. Other literature describing the ultrasonographic appearance of bursa in humans concluded that a ‘normal’ bursa is not visible [11], which is consistent with previous literature in equines demonstrating no evidence of an olecranon bursa in the normal equine elbow on ultrasonographic examination [4].

In animals, it is thought that subcutaneous bursitis occurs when a potential space becomes filled with fluid and eventually becomes encapsulated by fibrous tissue to form an acquired bursa [14]. In this study, dissection to assess gross anatomy involved predominantly sharp dissection techniques, because of the delicate nature of the bursa and attachments to the underlying tendons. Removal of a bursa with bursitis is less challenging due to dissection planes being more visible, and the capsule of the bursa being well-defined. Acute bursitis can be dry, serous or purulent, from which chronic bursitis can develop [15]. Chronic bursitis is characterized by increased bursal fluid, thickened wall, extrusions of fibrous bands within the cavity, and generalized subcutaneous thickening [1].

Table 2
CrCa radiographic contrast area measurements.

Measurement	Narrowest (cm)	Widest (cm)	Range (cm)	Mean (cm)
Width of the contrast area	2.93	6.35	3.42	4.36

Abbreviation: CrCa, craniocaudal.

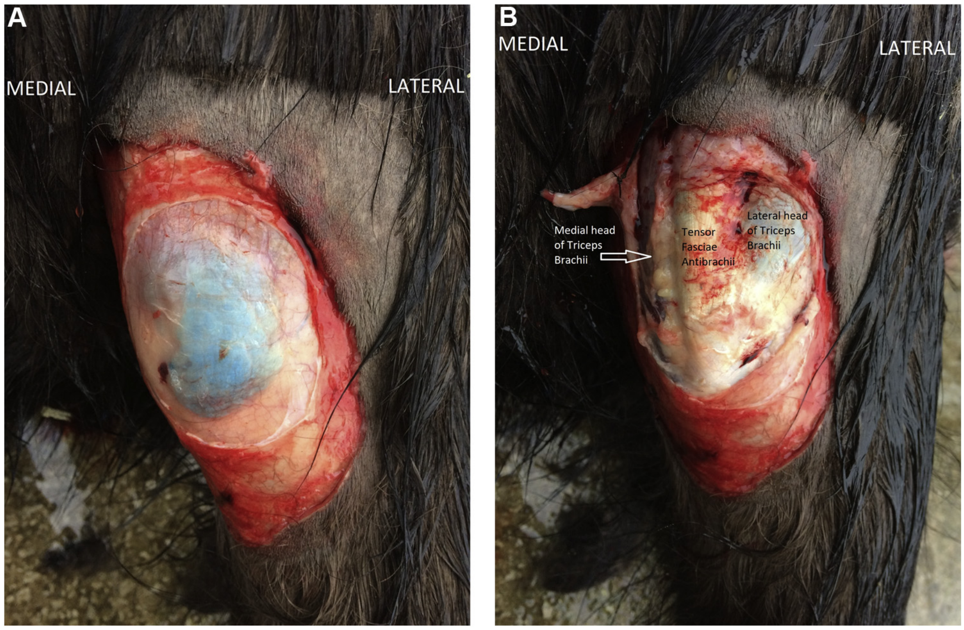

Fig. 4. Gross anatomical dissection of the silicone rubber–injected postmortem specimen. (A) Silicone rubber mix intact under the skin after initial incision and (B) underlying structures once the silicone rubber had been dissected.

The treatment of penetrating wounds to the olecranon bursa in horses is challenging because of the movement of the elbow joint and possible repetitive trauma to the olecranon tuberosity by the hoof when rising [13]. The decision of the veterinary surgeon to surgically remove or conservatively manage these affected olecranon bursae can be challenging. Anatomical landmarks of the space that incorporates an acquired bursa have been described in this study to assist the veterinary surgeon with removal of chronically affected olecranon bursae. Some may be effectively managed conservatively, especially in the acute injury phase [15]. Negative pressure wound therapy has been reported to aid in the treatment of a draining bursa [8]. Two of the three horses in this study had the olecranon bursa opened by the veterinary surgeon, resulting in worsening of clinical signs and a continuous open draining bursa [8].

Development of a chronic open draining olecranon bursa in horses causes slowed rate of healing due to movement and inability to protect the area [8]. A wound penetrating or overlying the olecranon tuberosity can be assessed with imaging modalities such as ultrasonography [11]. This can be used to evaluate damage or

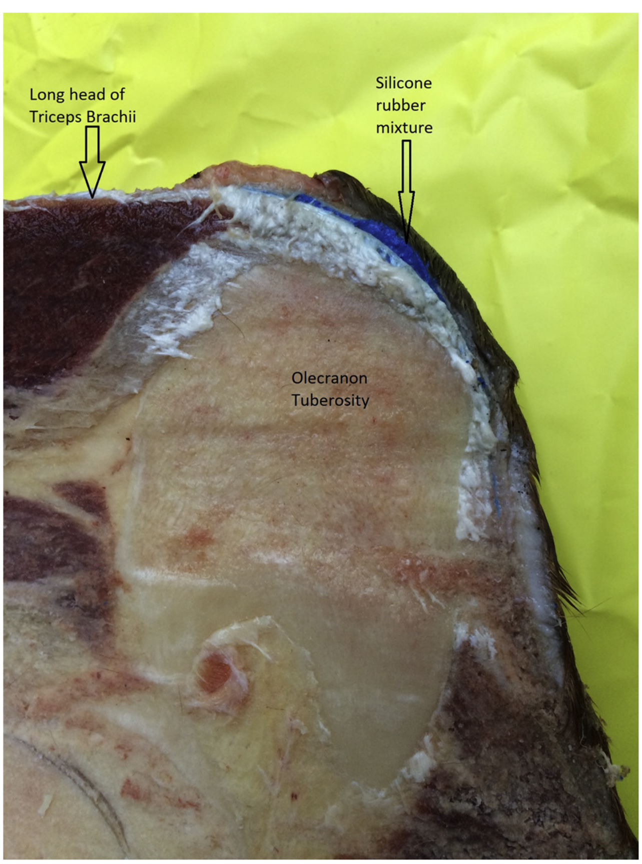

Fig. 5. Limb dissected in the sagittal plane showing the long head of the triceps brachii proximal to the olecranon tuberosity, and the silicone rubber overlying the tendon of insertion of the triceps. This demonstrates the subcutaneous nature of the potential bursal space.

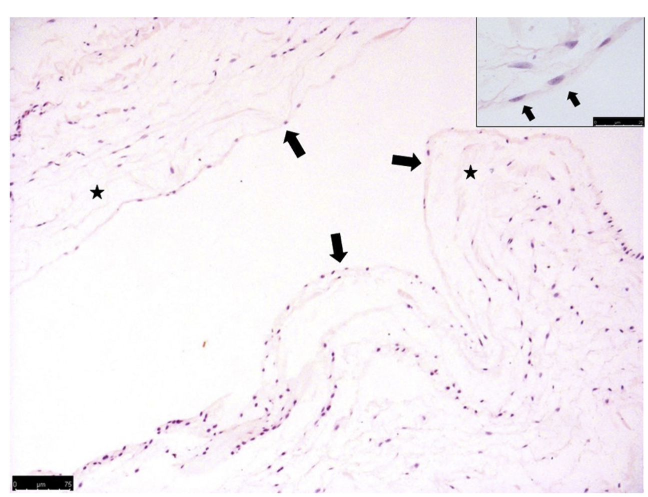

Fig. 6. Olecranon bursa lining characterized by single-cell thick membranes of spindloid cells (arrows), supported by an underlying loose moderately cellular stroma (*). HE. Bar 75 μm. Inset: single-cell thick membranes of spindloid cells (arrows). HE. Bar 25 μm.

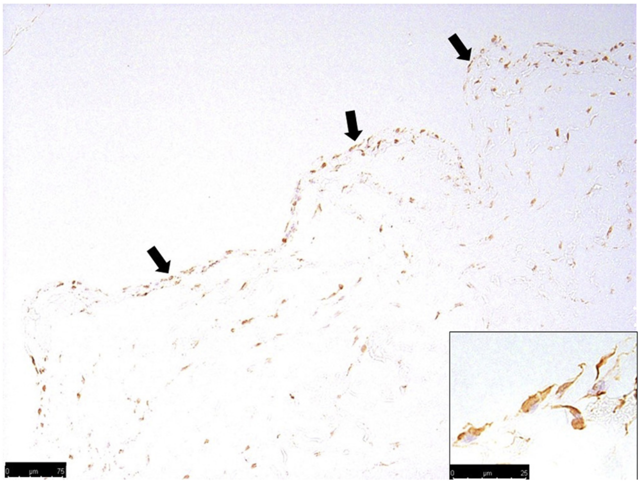

Fig. 7. Immunohistochemical (IHC) labeling of spindloid cell population (arrows) lining the bursa for vimentin (intracytoplasmic). Bar 75 μm. Inset: IHC of spindloid cell population (arrows) positive for vimentin (intracytoplasmic). Bar 25 μm.

communication of the wound to the tendons of the triceps brachii and tensor fasciae antebrachii and thus the likeliness of trauma to the bursa and subsequent development of bursitis.

Histopathology of the bursa showed features most suggestive of a congenital, rather than acquired (i.e., inflammatory) structure, because of the generally organized layered architecture, absence of inflammatory cells, and minimal proportion of fibrosis. There was no pathological bursa presented for histopathology in this study. A study of cattle and buffalo describing cases of cystic forms of olecranon bursitis found two to three layers of connective tissue-like cells on histopathology. Dense connective tissue was located directly beneath the cellular lining and formed from mature fibrocytes, fibrous tissue, and elastic fibers [14]. This is comparable to our study where the samples were found to have a thick single-cell lined membrane of spindloid cells. The lining of the bursae was identified to be of mesenchymal origin and was lined by fibroblast-like synoviocytes (type B synoviocytes).

Limitations of this study are that there are no ultrasound images over an affected bursa to support the anatomical location of the area filled with the silicone mixture. Further characterization of pathological bursae is required for comparison and is a point for further investigation. Further analysis to determine if the bursa is congenital with the assessment of foals or whether the bursa develops similarly to humans in early life. There was difficulty in keeping the degree of flexion/extension consistent between limbs of horses relating to a slight variation in radiographic positioning. In the gross anatomical dissection study, there was no control for height or horse or limb length, the only exclusion criteria included previous elbow lesions.

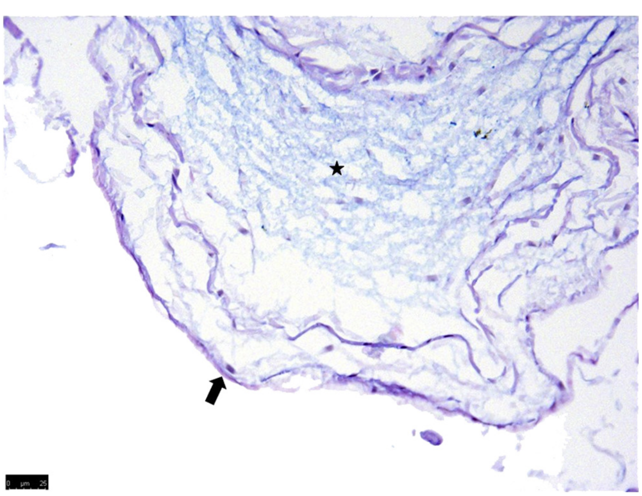

Fig. 8. Special stains using Alcian blue (at pH 2.5) with a periodic acid–Schiff (PAS) counterstain to highlight acid-simple mesenchymal mucin as the main matrix component of the underlying stroma, which is Alcian blue positive at pH 2.5 (*) and PAS negative. Cellular basement membranes are positive for PAS in this microphotograph (arrow). Bar 25 μm.

This study has shown that a bursa overlies the olecranon tuberosity in the absence of inflammation, confirming that an olecranon bursa develops in the absence of trauma to the elbow region. This study has outlined the anatomical landmarks of the olecranon bursa, which may assist veterinary surgeons in their management of traumatic injury to the caudal elbow and chronic bursitis cases.

5. Conclusion

A synovial lining is consistently present in horses older than 1 year in the absence of an inflammatory process. Further research is warranted to determine whether the synovial lining corresponding with an olecranon bursa is present since birth or develops at an early age of the horse (0–12 months old) as a result of physiologic pressure over the protuberant olecranon tuberosity. Histopathological analysis of distended bursae in cases of chronic bursitis would also improve our knowledge of the transformation from a normal to an inflamed olecranon bursa in the horse.

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